

LITHIUM BATTERY REQUIREMENTS FOR PLANETARY EXPLORATION

C.K. Huang, J. Sakamoto, M.C. Smart, R. Bugga, S. Surampudi, and S.G. Greenbaum*

NASA Jet Propulsion Laboratory, California Institute of Technology

Pasadena, CA 91109 USA

*permanent address, Hunter College of CUNY, New York, NY 10021 USA

Planetary exploratory mission spacecraft can be broadly classified into four types: orbiters, landers, rovers, and penetrators. Because of ever-present mass and volume design limitations, batteries intended for use on these exploratory missions have the common requirements of high specific energy and high energy density. Additionally, orbiters require long rechargeable cycle life whereas landers, rovers, and penetrators require the ability to operate at low temperatures. In particular, orbiters require batteries that can provide a specific energy > 100 Wh/kg and with a cycle life greater than 30,000 cycles (there is a charge/discharge cycle once each orbit) at 20-30 % depth of discharge (DOD). Conversely, landers and rovers require batteries that can provide > 120 Wh/kg and operate at temperatures -20 to 30°C but with a cycle life less than 500 cycles at 50-70% DOD. Also, penetrators require batteries that can operate at temperatures lower than -60°C and be able to withstand high shock levels ($\sim 80,000$ g).

Rechargeable batteries based on lithium ion chemistry offer specific energy values 2 to 3 times greater and energy density values 3 to 4 times greater than those of Ni-Cd and Ni-H₂ batteries currently in use in the space program. Also, they offer higher cell voltage and better coulombic and energy efficiency, a low self-discharge rate, and potentially lower battery costs compared to the Ni-Cd and Ni-H₂ batteries. These advantages can translate into several benefits for Mars Missions including reduced mass and volume of the energy storage subsystem, improved reliability, and extended mission life.

Four types of lithium cells are presently under development in the US, Europe, and Japan. These are: 1) lithium metal with liquid electrolyte, 2) lithium metal with polymer electrolyte, 3) lithium-ion containing liquid electrolyte, and 4) lithium-ion containing polymer electrolyte. Among these four types, lithium-ion containing liquid electrolyte battery technology is the most advanced as well as the most likely candidate for future space exploration missions (1998 and beyond). Currently, this technology is being considered by other aerospace organizations for use in geosynchronous- and low-earth orbit (GEO and LEO) spacecraft applications. Current Li-ion cells have a specific energy of about 80-120 Wh/kg and an energy density of 200-240 Wh/l, can operate at temperatures in the range of -10 to 30°C , and can deliver > 500 deep discharge cycles. For this technology to be applicable to future Mars exploration applications, however, improvements must be made to the design of these cells in order to meet specific mission requirements. These include increasing the cycle life of the cells, extending the operating range to lower temperatures, and scaling up the technology to larger cell sizes (5-20 Ah).

The use of polymer or gel electrolytes promises to further enhance the applicability of Li-ion electrochemistry to the space program in two important ways: 1) Polymer electrolytes and electrodes allow for the fabrication of thin, flexible cells which can be fitted to many varied form factors thus allowing batteries to be installed in any available space no matter what the form; 2) solid electrolytes eliminate the possibility of electrolyte leakage, thus greatly enhancing battery safety. Efforts to incorporate gel electrolyte technology into space battery research and development will be discussed.